Management Measure 7
Bridges and Highways

A. Management Measure

Plan, design, operate, and maintain highways and bridges to

- Protect sensitive ecosystems, including wetlands and estuaries, by minimizing road-building mileage in those systems, minimizing the number of water crossings, and establishing protective measures including setbacks during construction.
- Limit runoff of pollutants through the use and proper maintenance of structural controls.
- Limit generation of pollutants from maintenance operations by minimizing the use of pesticides, herbicides, fertilizers, and deicing salts and chemicals.
- Limit generation and runoff of pollutants during highway and bridge repair operations by reducing the use of hazardous materials and incorporating measures to prevent spillage into sensitive areas.

B. Management Measure Description and Selection

1. Description

Motor vehicles generate runoff pollutants through emission and deposition of automobile exhaust and through discharges of both fluids and solid particles during travel and while braking. In a study of traffic-generated particulates in Cincinnati (where the average daily traffic is 150,000 vehicles), Sansalone and Buchberger (1997) found that of the 13,500 mg of particulates per square meter of road surface generated per day, 44 to 49 percent originated from pavement wear, 28 to 31 percent from tire wear, and 15 percent from engine and brake pad wear. The study also found that 6 percent of particulates were deposited from settleable exhaust and 3 percent from atmospheric deposition.

A study by Shepp (1996) examined generation and control of petroleum hydrocarbons in urban runoff from four land uses: all-day parking lots, streets, gas stations, and convenience commercial areas. Shepp found that convenience commercial areas had the highest hydrocarbon concentration (see Figure 4.31). Evaluation of the observations and their respective catchment areas suggested that the degree of automotive exposure (a combination of duration of exposure to vehicles with engines running and volume of traffic) is the primary factor in the generation of petroleum hydrocarbons in runoff from automotive-intensive land uses.

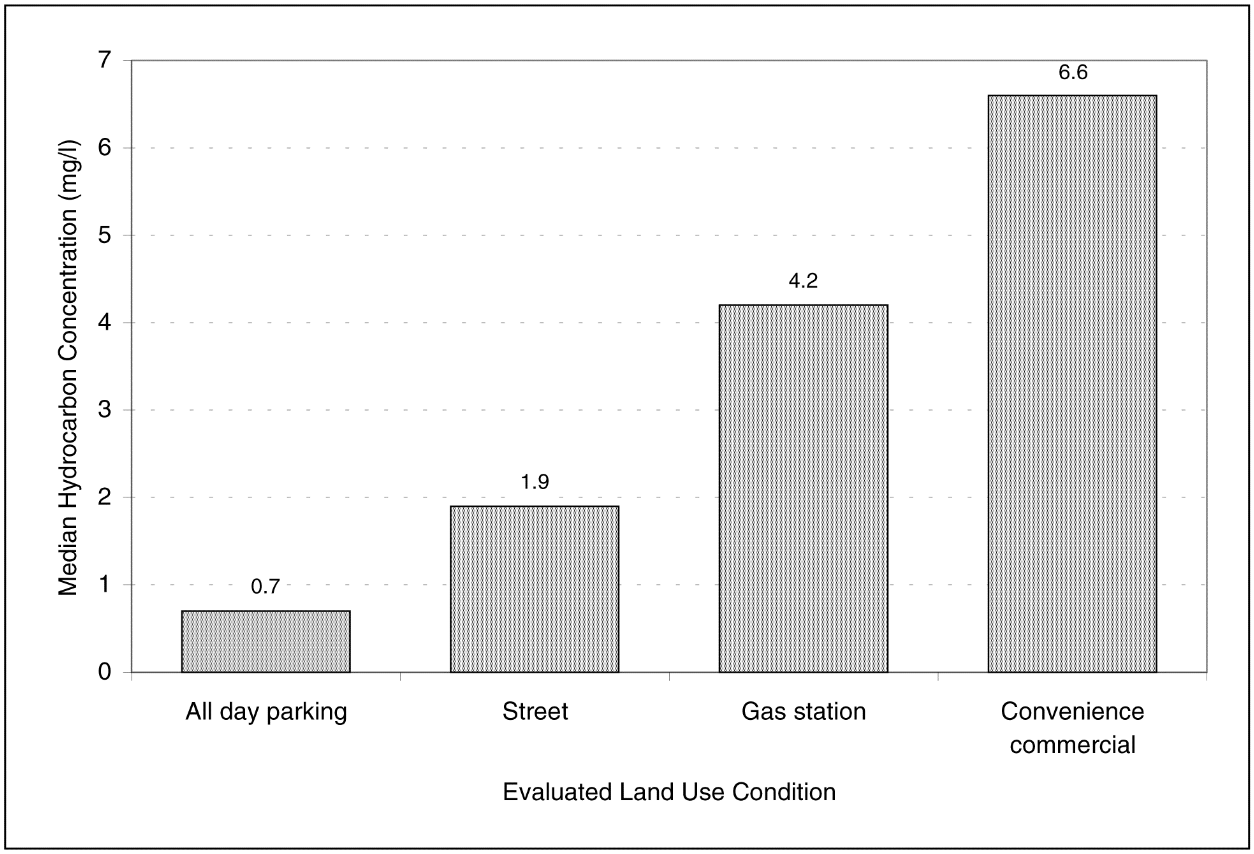

Figure 4.31: Median hydrocarbon concentrations by land use (Shepp, 1996).

The National Water Quality Assessment Program (NAWQA) of the U.S. Geological Survey recently conducted studies on water pollution related to sprawl-induced traffic. These studies show a consistently positive correlation between increases in vehicular traffic associated with urban sprawl and the buildup of polycyclic aromatic hydrocarbons (PAHs) in 10 lakes and reservoirs in six metropolitan areas across the country. PAH sources related to motor vehicle use include tire wear, roadway wear, exhaust and soot, and crankcase oil releases (Van Metre et al., 2000).

Roads tend to accumulate particulate matter from roadsides, salting and sanding, dirty cars, brake pad dust, aerial deposition, and road surface deterioration. Sansalone and Tribouillard (1999) and Sansalone et al. (1998) measured the deposition and size distribution of particles deposited on highways. They found that accumulation of particulate matter was significantly greater along the downslope of the highway than along the upslope and that particle size distributions (PSDs) along the downslope were consistently coarser across the entire size gradation than the upslope and pavement PSDs (Sansalone and Tribouillard, 1999). Solids in the 2 to 8 µm range generated the largest counts and were rapidly washed from the pavement in a “first flush” effect (Sansalone et al., 1998). Lateral pavement sheet flow rate and duration controlled the yield and size of transported solids; particle transport was mass-limited during long-duration, high-intensity events but flow-limited during intermittent, low-intensity events with high traffic (Sansalone et al., 1998).

These particles, when transported in runoff to receiving waters, contribute to high levels of total suspended solids and turbidity and act as a carrier for other pollutants that adhere to particle surfaces. Because of this adsorption phenomenon, surface area can be an important determinant in pollutant loading from highways. A relationship exists between particle size and surface area. Sansalone et al. (1998) found that particles 425 μm to 850 μm in size contributed the greatest total surface area. Sansalone and Tribouillard (1999) found that total surface area decreased with decreasing particle size. Particle-specific surface area, however, increased with decreasing particle size (Sansalone and Tribouillard, 1999; Sansalone et al., 1998), but measured values deviated from the monotonic pattern expected for spherical particles (Sansalone et al., 1998).

Because total surface area is predominantly associated with the coarser fraction, heavy metal mass (adhered to particle surfaces) is also strongly associated with this fraction (Cristina et al., 2000). Cumulative analyses for lead, copper, cadmium, and zinc in snow residuals indicated that more than 50 percent of these heavy metals (by mass) was associated with particles greater than 250 μm and more than 80 percent was associated with particles greater than 50 μm (Sansalone and Glenn, unpublished c).

Heavy metals such as lead, iron, and aluminum are typically particulate-bound in urban runoff (Sansalone and Buchberger, 1997). Sansalone and Glenn (2000), however, found that lead was predominately dissolved in highway runoff, a phenomenon they attributed to low urban rainfall pH and alkalinity and relatively short pavement residence times. Other metals predominately found in the dissolved phase in highway runoff were zinc, cadmium, and copper (Sansalone and Buchberger, 1997; Sansalone and Glenn, 2000).

The partitioning of heavy metals between the particulate-bound and dissolved fractions raises important questions for watershed managers regarding storm water treatment. It was previously thought that metals were associated with particulates and that removing sediment and reducing turbidity would address these pollutants. However, new research indicates that event mean concentrations of dissolved zinc, cadmium, and copper can exceed surface water quality discharge standards and can exhibit a “first flush” effect that cannot be mitigated by settling. In addition, the dissolved nature of these metals makes them highly mobile and bioavailable.

Other pollutants found in highway runoff are shown in Table 4.25 along with their likely sources. Although runoff characteristics tend to be site-specific, a number of studies have been performed to compile typical concentrations of highway pollutants from a range of different locations from Northhampton, England, to Durham, North Carolina. Table 4.26 shows the range of values for highway contaminants presented by Newbry and Yonge (1996). These concentration levels vary significantly among the different locations. Suspended solids, for example, had concentration levels ranging from 45 mg/L to 798 mg/L; ranges for other parameters were even greater. For some pollutants, such as solids, heavy metals, and organics, concentration levels have been found to correlate with traffic volume.

Table 4.25: Primary sources of highway runoff pollutants (Adapted from NCHRP, 1999).

Pollutants	Primary Source
Particulates	Pavement wear and vehicle maintenance
Lead, cadmium, copper	Tire wear, lubricating oil and grease, bearing wear
Nitrogen, phosphorus	Roadside fertilizer application
Chromium, copper, nickel, cadmium	Metal plating, moving engine parts, brake lining wear
Chloride, sulfates	Deicing salts
PCBs, pesticides	PCB catalyst in synthetic tires, spraying highway rights-of-way
Cyanide	Anti-cake compound used to keep deicing salt granular
Petroleum, ethylene glycol	Spills and leaks of motor lubricants, antifreeze, hydraulic fluids

Table 4.26: Range of average values for runoff contaminant concentration for selected highway contaminants (Newbry and Yonge, 1996).

Contaminant	Concentration (mg/L)	Load (kg/ha/yr)	Load (kg/ha/event)
Suspended solids	45–798	314–11,862	84–107.6
Lead	0.073–1.78	0.08–21.2	0.008–0.22
Phosphorus	0.073–1.78	0.6–8.23	—
Biological oxygen demand	0.113–0.998	30.6–164	0.98
Polycyclic aromatic hydrocarbons	12.7–37	0.005–0.018	—

Runoff from the construction, operation, and maintenance of highways and bridges can adversely affect vegetation, surface waters, and wetlands with a variety of pollutants, including sediments, heavy metals, hydrocarbons, and toxic substances. Runoff issues associated with construction of highways and bridges are addressed in Management Measure 8—Construction Site Erosion, Sediment, and Chemical Control. Although the runoff constituents and concentration levels vary with highway type and location, the sources of highway runoff pollutants fall into three basic categories: vehicle traffic, snowmelt and ice-melt containing deicing chemicals, and chemicals used to manage roadside vegetation.

The specific impacts of highway and bridge runoff on aquatic ecosystems are both site-specific and runoff-event-specific. In general, highway pollutants can affect water quality through either acute toxicity or gradual accumulation. Potential adverse environmental effects associated with specific constituents include the following:

- *Suspended solids* increase turbidity, transport other pollutants adhered to particle surfaces, and reduce runoff storage capacity in ponds and lakes.

- *Heavy metals* are toxic to many aquatic organisms and can bioaccumulate in fish tissues, thus posing potential health risks to humans.

- *Nutrients* degrade water quality by stimulating the growth of algae and aquatic weeds. Rapid increases in these populations can then deplete oxygen levels to the extent that fish and other aerobic organisms die off.

- *Biochemical oxygen demand (BOD)* reduces dissolved oxygen levels as a result of the biological processes that break down organic constituents in runoff.

– *Polycyclic aromatic hydrocarbons (PAHs)* include compounds such a benzo(a)pyrene that are found in petroleum products and are carcinogenic. These compounds can pose risks to human health if drinking water or fish become contaminated with them. PAHs in streams and lakes usually do not pose a health risk for people because they tend to adhere to sediment particles rather than dissolve in water. As a result, the risk of drinking water degradation is low (Van Metre et al., 2000).

Paved roadways often generate higher loads of metals and toxicants than other nonpoint source pollutants. Nutrient loadings from highways tend to be of concern when they are located upstream of a reservoir or estuary. It should be noted that several recent studies cited by the Federal Highway Administration indicate that few significant environmental impacts have been associated with roads with an average daily traffic volume of less than 30,000 vehicles (USDOT, 1996).

Winter maintenance activities to prevent ice and snow buildup on highways can also be significant contributors to loadings of particulates, salts, and various other chemicals. Salts in particular can harm both vegetation and aquatic ecosystems. Other highway maintenance activities, including roadside vegetation management, can also contribute herbicides, pesticides, and nutrients to runoff pollutant loads.

In several unpublished studies, Sansalone and Glenn (unpublished a, b, and c) examined the characteristics of snowbanks and snowmelt. Table 4.27 summarizes their findings for several pollutants and physical characteristics. From their research, they concluded the following:

– Traffic and winter maintenance practices generate significant levels of inorganic and organic constituents, many of which become predominately particulate-bound in the snowbank with increasing residence time.

– The accretion of traffic-generated constituents in urban highway snow is relatively rapid within the first 12 hours of the snowbank's exposure to traffic.

A research team at Oregon State University, under the National Cooperative Highway Research Program (NCHRP, 2000) identified potentially mobile constituents from highway construction and repair materials and measured their potential impact on surface and ground waters. The materials tested were conventional, recycled, and waste materials; and excluded constituents originating from construction processes, vehicle operation, maintenance operations, and atmospheric deposition. The research team established laboratory methods to realistically simulate the leaching of constituents from construction and repair materials in typical highway environments and to evaluate the removal, reduction, and retardation of leached constituents by environmental processes in the highway right-of-way. The team produced extensive data sets of laboratory test results for highway construction and repair materials and expressed the results as aquatic toxicity and chemical concentrations. They then developed a software program called IMPACT, which estimates the fate and transport of leachates surrounding the highway right-of-way. IMPACT contains an extensive, readily accessible database of laboratory test results for materials ranging from common construction and repair products to waste and recycled materials proposed for use in highway construction.

Table 4.27: Results of three studies that analyzed chemical and physical parameters of snowmelt (Sansalone and Glenn, unpublished a, b, and c).

Parameter	Result
Bulk density	Bulk densities increased as TSS accumulation continued and the snow matrix began to melt or evaporate.
Particle size distribution and bulk density	For all sites, particle sizes ranged from 10,000 µm to less than 25 µm, with a mean bulk density of 1,225 µm.
Specific gravity	Specific gravity of residual solids ranged from 2.5 to 3.2 g/cm^3 across the gradations; the lower specific gravity was associated with particles less than 100 µm.
Chloride and conductivity	Conductivity and chloride concentrations increased rapidly at first because of initial deicing salt applications at each site. Strong correlations indicated that conductivity trends were mainly a function of chloride trends.
Hardness	Hardness increased rapidly to nearly 100 mg/L during initial snow accumulation and remained relatively constant (100–300 mg/L) for most of the study. This increase is likely a result of liquid $CaCl_2$ mixed with rock salt and $CaCO_3$ as part of the TSS captured by the snow matrix.
COD	Temporal trends toward increasing total chemical oxygen demand (COD) exerted by roadway snow are similar to trends in TSS, with COD values of 100,000 mg/L.
TDS and TSS	Although accretion of total dissolved solids (TDS) was initially rapid with a decrease late in the event, total suspended solids (TSS) accretion demonstrated a more gradually increasing trend for the duration of roadway snow, approaching 100,000 mg/L.
Cyanide	Applications of 216,000 kg of rock salt containing cyanide as an anti-caking agent resulted in a discharge of approximately 6 kg of cyanide along the interstate.
Metals	Concentrations for lead, copper, cadmium, zinc, and cyanide were orders of magnitude higher than those of the control site and exceeded storm water runoff concentrations by 1 to 2 orders of magnitude.

Note: TSS = total suspended solids, TDS = total dissolved solids, COD = chemical oxygen demand, $CaCl_2$ = calcium chloride, $CaCO_3$ = calcium carbonate.

2. Management Measure Selection

This management measure was selected to provide general guidance on practices that can be integrated into highway and bridge maintenance and repair operations. The management measure also includes guidance for siting and constructing highways and bridges. The watershed protection; site development; new development runoff treatment; and construction site erosion, sediment, and chemical control management measures (Management Measures 3, 4, 5, and 8) discussed previously are also applicable to the planning and constructing of highways and bridges.

C. Management Practices

The use of structural and nonstructural runoff control practices during the planning, design, operation, and maintenance of highways and bridges can significantly mitigate the adverse effects of runoff. Specifically, by using environmentally sensitive highway and bridge designs and implementing proper operation and maintenance practices, highway authorities can reduce both the volume and concentration of contaminants generated by motor vehicle traffic and maintenance and repair operations. In addition, controls can be used to store and treat contaminants so that pollutant loadings can be further reduced or prevented from entering sensitive ecosystems.

1. Site Planning and Design Practices

A wide range of environmental planning and design management practices, especially those presented in Management Measures 3 and 4, can be used to reduce the environmental impacts of highways and bridges and can be initiated long before a road is completed. In general, highways and bridges should be planned to minimize mileage through sensitive environments, such as wetlands and estuaries. River crossings should be minimized, and sufficient setbacks should be established during construction to minimize disturbance of the surrounding environment.

Highway development is most disruptive in wetland areas because it increases sediment loss, alters surface drainage patterns, changes the subsurface water table, and results in loss of wetland habitat. Highway structures should not restrict tidal flows into salt marshes and other coastal wetland areas because such restrictions might facilitate the intrusion of freshwater plants and reduce the growth of salt-tolerant species. To safeguard these fragile areas, highways should be sited with sufficient setback distances between the highway right-of-way and any wetlands or riparian areas.

Bridge construction can also adversely affect water circulation and quality in wetland areas, necessitating special techniques to accommodate construction. By locating highways and bridges away from sensitive areas and establishing buffer zones where possible, environmental degradation from erosion and runoff can be mitigated during construction, operation, and maintenance of roadways.

2. Structural Runoff Controls for Highways

Soil bioengineering techniques can be used to augment or replace structural slope stabilization practices such as retaining walls. They are appropriate for relatively moderate slopes where vegetation can be established readily. Installation of bioengineering practices can be labor-intensive, and periodic inspection and maintenance, especially after large storm events, is necessary to repair slumps and replace dead vegetation. Several kinds of soil bioengineering practices are described by the U.S. Department of Agriculture (USDA, 1992):

a. Live stakes

The use of live stakes involves inserting and tamping live, rootable vegetative cuttings into the ground to create a living root mat that stabilizes the soil by reinforcing and binding soil particles together and by extracting excess soil moisture. Live stakes are appropriate for repairing small earth slips and slumps caused by excessively wet soil and should be used only at sites with relatively uncomplicated conditions. They are especially useful when construction time is limited and an inexpensive method is desired. They can be used to secure erosion control measures and can be used in combination with other bioengineering techniques. Finally, they facilitate plant colonization by providing a favorable microclimate for plant growth.

b. Fascines

Fascines are long bundles of branch cuttings bound together into sausage-like structures. They are installed in contoured or angled trenches and are secured to the slope with both live and dead stakes. They reduce surface erosion and rilling, protect slopes from shallow slides, and reduce long slopes into a series of shorter slopes that trap and hold soil. They also enhance vegetative growth by creating a microclimate conducive to plant growth.

c. Brushlayers

Brushlayering is much like the fascine technique except branches are placed perpendicular to the slope contour. This method is more effective than fascines with respect to earth reinforcement and mass stability. Brushlayers break up the slope length, preventing surface erosion, and reinforce the soil with branch stems and roots, providing resistance to sliding or shear displacement. Brushlayers also trap debris, aid infiltration on dry slopes, dry excessively wet sites, and mitigate slope seepage by acting as horizontal drains. Brushlayers facilitate vegetation establishment by providing a stable slope and a favorable microclimate for growth.

d. Branchpacking

Branchpacking involves reinforcing a slope with alternating layers of live branch cuttings and compacted backfill. This technique is useful to repair small, localized slumps and holes in earthen embankments other than dams. Branchpacking produces a filter barrier that reduces erosion and scouring and provides immediate soil reinforcement. Branchpacking is not effective in slump areas greater than 4 feet deep or 5 feet wide.

e. Live gully repair

Live gully repair is a technique that is similar to branchpacking but is used to repair rills and gullies. Live gully repairs offer immediate reinforcement and reduce the velocity of concentrated flows. They also provide a filter barrier that reduces further rill and gully erosion. This technique is appropriate only to repair rills or gullies less than 2 feet wide, 1 foot deep, and 15 feet long.

f. Live cribwalls

A live cribwall is a hollow, boxlike structure of interlocking untreated logs or timber members installed with backfill material and layers of live branch cuttings. The live cuttings eventually take over the structural functions of the wall once the roots have become established. Live cribwalls are appropriate for stabilizing the toe of a slope and reducing its steepness. They should not be used in areas that are subject to large lateral stresses. Cribwalls provide both immediate and long-term stabilization and are useful where space is limited. They should be tilted if the system is built on a smoothly sloped surface, or they can be constructed in a stair-step fashion.

g. Vegetated rock gabions

Vegetated rock gabions consist of wire mesh or chain-link baskets layered with live branch cuttings that take root inside the gabions and bind the structure to the slope. These structures are appropriate for stabilizing the toe of a slope and reducing its steepness, especially in areas where space is limited. They should not be used in areas that are subject to large lateral stresses and should not be more than 5 feet tall.

h. Vegetated rock walls

Vegetated rock walls consist of a combination of rocks and live branch cuttings used to stabilize the toe of steep slopes. These structures are appropriate for stabilizing areas where space is limited and natural rock is available. The wall should not exceed 5 feet in height.

i. Joint planting

Joint planting stabilizes slope faces by planting live cuttings in spaces between the stones of riprap. The plantings improve drainage, bind rock materials to the slope, and help prevent washout of fine materials. Joint planting can be used where riprap has already been installed, or it can be part of a new riprap installation.

j. Other runoff and sediment controls for highways

Other runoff controls, such as grassed swales, wet ponds, extended detention dry ponds, storm water wetlands, and grassed filter strips, can be used to control highway runoff. These measures are described in detail in Management Measure 5. Additionally, sediment traps and basins and inlet protection (described in Management Measure 8) can be used to collect runoff from highways, especially during construction and repair operations when pollutant loadings are great.

Low Impact Development along Highway Rights-of-Way in Lenexa, Kansas

The City of Lenexa, Kansas, has proposed to treat nearly 100% of the first inch of runoff from the Prairie Star Parkway using a combination of bioretention areas, a constructed wetland, and a wet pond. Off-site drainage from upstream development will bypass the bioretention areas, be directed into a sediment forebay, and eventually be treated by the constructed wetland.

3. Structural Runoff Controls for Bridges

a. Scupper drains with runoff conveyance systems

Bridges have traditionally been designed to direct runoff away from the roadway as efficiently as possible without regard to impacts on the environment below the deck. More recently, bridge designs have taken into account potential effects of runoff pollutant loadings, especially on waterbodies. The most prevalent mitigation practice is to direct the drainage from the bridge to an on-shore treatment system. For example, the runoff can be conveyed from scupper drains through a pipe onto the shore, from which it is sent to a retention pond or other runoff treatment practice. A scupper drain is an opening in the floor of a bridge that provides a means for rain or other water accumulated on the roadway surface to drain into the space beneath the structure (ODOT, 2001). Rather than draining directly to the water below, the runoff can be routed to the shore for treatment.

The Federal Highway Administration (FHWA) and EPA have developed recommendations on the design and use of scupper drains to address bridge deck runoff. Among the practices they recommend are the following:

- The spacing between scuppers should be maximized in accordance with established maximum hydrologic and hydraulic design. As scupper spacing increases, the volume of water that passes through each scupper increases, thus creating velocities high enough to flush outlets clogged by deposits from low-volume rainfalls.

- Careful detailing is critical when connecting scuppers to drain pipes. Because of poorly designed routing, drain pipes have often created more problems than they have prevented.

For example, piping that is routed with too many elbows can easily clog, resulting in a buildup of contaminated runoff.

– Gravity flow collection systems should be used wherever possible.

Collection systems for scupper drains might not be a cost-effective approach to minimizing the impacts of bridge runoff. Depending on the length of the bridge and traffic volume, as well as river size and climate, bridge runoff might constitute only a small fraction of the overall pollutant load to a receiving water. Furthermore, the topography and approach slope at some bridge locations might preclude design or retrofit for gravity drainage back to land, therefore requiring the use of a pump to discharge the runoff into a suitable water quality treatment practice. The addition of pumps could significantly increase the cost of the collection system and operation and maintenance requirements. In some cases, controlling runoff from other pollutant sources might be more cost-effective when a watershed approach is used.

b. Other runoff treatment practices

Runoff treatment practices like ponds, wetlands, infiltration basins and trenches, media filters, bioretention areas, vegetated swales, filter strips, and hydrodynamic devices (see Management Measure 5) can be installed on the shore to treat runoff collected and routed by scupper drains and pipes. If a bridge does not have scupper drains, runoff can be routed to the shore via gutters. Depending on site conditions, such as the space available for the practice, the suitability of the soils for filtration or infiltration, and the quantity and quality of the bridge runoff, some practices might be more cost-effective than others.

4. Bridge Operation and Maintenance Controls

Bridge repairs are those activities necessary to maintain the structural integrity and designated use of the bridge. Bridge repairs encompass a wide array of activities, ranging from minor operation practices such as line painting to major structural repairs. Bridge scraping and painting, which is required to prevent corrosion, can be a significant source of pollutant loads if proper management practices are not used.

Although most construction activities take place away from waterbodies, bridge operation and maintenance activities occur within close proximity to a waterbody. Therefore, management practices to minimize potential adverse effects on the surrounding environment are recommended.

a. Enclosures

The following types of enclosures can be used to collect pollutants during bridge maintenance activities:

(1) *Free-hanging enclosures*. Free-hanging enclosures include tarps, drapes, plastic sheeting, screens, and rigid panels in which only two corners or one side of the sheeting or panel is supported. Free-hanging tarps generally result in relatively low containment efficiency (estimated at no more than 50 percent). Considerations for material selection include visibility inside the enclosure, material strength, and air permeability. Free-hanging

enclosures are not practical for large, high bridges where high winds can rip the materials or create a “sail effect.”

(2) *Total structural enclosures*. Total structural enclosures are drapes, tarps, screens, plastic sheeting, or rigid panels attached to a rigid steel or wood framework, scaffolding, or existing walls. Design considerations include interior air quality, visibility, the structural adequacy of the enclosure, portability, and reusability. Enclosures may be used to encapsulate only part of a large structure at a time. Therefore, portability and reusability should be considered.

(3) *Negative pressure systems*. Negative pressure containment systems are used to prevent dust from escaping an enclosure when pressurized air blasting is used for paint removal. Such systems draw outside air into the enclosure to the surface being treated; the air then exits through a filter system. The resulting continuous air exchange eliminates leaks of paint dust and abrasives to the outside, improves worker visibility, and reduces health hazards and dust accumulation on structure surfaces and equipment. These systems can be cumbersome and expensive, however, and it is sometimes difficult to maintain a constant negative pressure in the enclosure.

b. Containment and collection

The following practices can be used to contain and/or collect pollutants during bridge maintenance activities:

(1) *Cofferdams*. Cofferdams are temporary structures used to displace water and provide dry access to submerged support structures for bridges. Cofferdams can be used during bridge construction and maintenance operations involving painting or repairing of steel structures that are in contact with the waterbody.

(2) *Barges*. Barges situated below the bridge with tarps or shields attached from the barge to the bridge or work platform can be used for debris capture, although winds often make this practice infeasible.

(3) *Containment booms*. Containment booms can be placed in underlying waters to capture floating debris (e.g., paint chips, fines). Lead particles and abrasives usually sink, but use of booms keeps these materials from spreading downstream while they are suspended in the water column.

(4) *Vacuum sanders*. Vacuum sanders can be used to remove paint from bridges and collect dust and chips. Sanders have been shown to immediately capture 98 percent of the dust generated, which reduces cleanup of containment areas and offers increased safety to maintenance workers (USEPA, 2001).

5. Nonstructural Runoff Control Practices

The structural management practices for highways and bridge decks described previously are designed to reduce pollutant loadings to the environment by holding and treating the highway runoff generated by a precipitation event. Nonstructural management practices are designed to achieve source control and can be used to augment on-site structural or other runoff management facilities. Most of the nonstructural practices for managing highway runoff pollution are applicable to virtually all highway situations, even if a specific runoff problem has not been identified.

The following management practices for highway runoff are intended to reduce the volume of particulates available for transport by runoff or to filter and settle out suspended solids. Although the practices described do not represent the complete universe of highway management practices, they are among those commonly implemented across the United States.

a. Eliminate curbs

Curb systems act as traps for particulates and other pollutants. Eliminating curbs from roads and highways allows runoff to be filtered through vegetated shoulders or medians and infiltrate to the ground water. Where curbs are necessary for traffic control or other reasons, curb breaks can be incorporated to direct runoff to pervious areas. The advantage to curbs is that they trap pollutants on the paved surface, and when combined with regular vacuum street sweeping programs (where available), they can be effective at removing pollutants prior to mobilization in runoff.

b. Control litter and debris on roadsides

Roadside litter control practices that have traditionally been implemented to address health and aesthetic concerns can also improve runoff quality by limiting trash in runoff conveyance and treatment systems and receiving waterbodies. An effective litter and debris control program should include the following source controls:

- Conducting regular trash and debris removal and disposal.
- Educating the public with signs along roads and at rest areas.
- Enforcing littering and illegal dumping laws.
- Sealing cracks and applying pothole surface treatments that minimize the loosening of aggregate and road base debris by tires.
- Sponsoring Adopt-A-Highway or Adopt-A-Road programs. Many state highway administrations or departments of transportation sponsor Adopt-A-Highway programs that allow businesses and community groups to conduct litter removal and beautification activities on state-owned roads. The city and county equivalent is called Adopt-A-Road.

c. Manage pesticide and herbicide use

Overapplication of pesticides and herbicides results in excess chemicals being readily leached from the soil by rainfall into surface runoff or underlying ground water. Herbicides and pesticides have the same toxic effect on aquatic plants and organisms as they do on the terrestrial plants and organisms to which they were applied. Practices such as applying according to label instructions, at the proper time, applying only the types and amounts necessary, and considering the environmental conditions and hazards at the site are important ways to prevent pesticides and herbicides from entering waterbodies.

d. Reduce fertilizer use

Improper application of fertilizers along roadsides can result in excess nutrients being transported to surface waters or leaching to ground water. Methods to reduce fertilizer use are presented in detail in Management Measure 9 (section C.2).

e. Reduce direct discharges

Direct discharges of highway runoff to receiving waters should be avoided wherever possible. This involves the use of collection/conveyance through closed conduits. Highway runoff should be routed through one or a combination of runoff treatment practices, as described in Management Measure 5, before it is discharged to receiving waters.

f. Practice dewatering

Dewatering is a temporary method used to filter sediment-laden water from excavated areas on construction sites prior to discharge to a storm drain or surface waters. Dewatering pumps are applicable wherever sediment-laden water must be removed from a construction site. Dewatering practices should be considered a last-resort control measure. Adequate erosion and sediment control measures must be considered first.

g. Practice spill prevention and control

Prevention and control of spills eliminates or minimizes the discharge of pollutants to waterbodies. Waterbodies adjacent to construction sites are at highest risk of contamination from an uncontained spill. Several steps can be taken to reduce the risks: handle hazardous and nonhazardous materials, such as concrete, solvents, asphalt, sealants, and fuels, as infrequently as possible and observe all federal, state, and local regulations when using, handling, or disposing of these materials. Spill control devices such as absorbent snakes and mats should be placed around chemical storage areas and can be used in an emergency to contain a spill.

h. Properly handle and dispose of concrete and cement

Concrete and cement-related mortars can be toxic to aquatic life. Proper handling and disposal should minimize or eliminate discharges into watercourses. Fresh concrete and cement mortar should not be mixed on-site, and both dry and wet materials should be stored away from waterbodies and storm drains. These materials should be covered and contained to prevent contact with rainfall or runoff. Washout should not be discharged into streets, storm drains, drainage ditches, or watercourses. A washout area should be designated, and wash water should be treated on-site or discharged to the sanitary sewer.

i. Manage contaminated soil and water

Soil, ponded runoff, and ground water can become contaminated if exposed to hazardous materials and should be properly managed to prevent health hazards and minimize or eliminate discharge of pollutants to the storm drains and watercourses. Excavation, transport, and disposal of contaminated soil and water as well as hazardous waste must be in accordance with the rules and regulations of EPA, the U.S. Department of Transportation, the Department of Toxic Substances Control, and state and local regulatory agencies.

j. Practice environmentally friendly winter road maintenance

Some of the most damaging runoff can be generated from the melting of snow or ice that has been treated with salts or other chemicals. For example, the buildup of salts along roadsides over the course of a winter can damage and reduce the effectiveness of structural controls such as vegetative filter strips and grass-lined channels. Salts in surface or ground waters can adversely affect water quality and damage wetlands. The corrosive effects of salts also damage road infrastructure, especially bridge decks. According to the Transportation Research Board (1991), road salt has caused more premature bridge deck deterioration than any other factor.

Deicing chemicals deposited on road surfaces can contaminate runoff, as can chemicals that are stored such that they come in contact with precipitation or runoff. Chemicals can also enter receiving waters if chemically treated, plowed snow is piled in areas that are connected to receiving waters via impervious surfaces. For example, piling salted snow on a parking lot surface can result in runoff of the chloride-laden water directly to a stream or runoff treatment pond. Treated snow should never be stored on a frozen pond surface because it can cause density stratification, which can prevent reoxygenation, in addition to chloride problems.

Three general types of management practices can be employed to reduce the impacts of salt damage on the environment. The first is to implement anti-icing operations that help reduce the amount of chemicals required to maintain safe road conditions; the second is to use alternative deicing materials, which are less corrosive and are presumably less damaging to the environment. The third is to properly store salts or other deicing chemicals to prevent runoff contamination.

(1) *Anti-icing operations*. Anti-icing operations are performed before a storm starts. The purpose of these operations is to prevent snow or ice from accumulating on road surfaces. One of the main advantages of successful anti-icing strategies is that they can reduce the amount of chemicals and abrasives used to keep roads clear. Since 1994, 15 states have participated in the FHWA's project to test and evaluate the effectiveness of anti-icing operations. Anti-icing operations typically use the same chemicals used for deicing, but in different forms. For example, test results found that prewetting deicing salt and using brine solutions are effective approaches and result in fewer handling problems.

The ultimate success of anti-icing operations depends on the timing of application. Central to this approach is the use of Roadway Weather Information Systems (RWIS), which report road conditions through pavement sensors that monitor pavement temperatures and the amount of anti-icing materials present on the pavement. When this information is combined with meteorological data and fed into a central database, various modeling techniques can be applied to accurately predict the start of ice formation on pavements and the appropriate times to start anti-icing operations. The cost of implementing and maintaining an RWIS must be compared against savings in labor and materials. Successful use of the RWIS leads to fewer applications of deicing materials and fewer snowplow trips. The West Virginia Parkway Authority installed four RWIS units along a 95-mile stretch of highway and calculated that the agency was able to save sufficient outlays for materials and labor to pay for the system within a year. In a state with fewer snowstorms, however, the economics of installing an RWIS may be less advantageous.

(2) *Alternative deicers*. Over the years, the FHWA and numerous states have experimented with alternative deicing chemicals, including liquid calcium magnesium acetate (CMA), liquid calcium chloride, liquid magnesium chloride, and liquid potassium acetate. Research has found that these chemicals have both advantages and disadvantages compared to salt (see Table 4.28). Calcium chloride works better at lower temperatures but is also corrosive. CMA appears to be much less harmful to the environment. Its disadvantage is that it is significantly more expensive than salt; the NRC estimated that CMA can cost 20 times more than salt and would increase the total cost of chemical application five-fold (Chollar, 1996). CMA is also less successful than other salts at lower temperatures and is slower to act than salt.

In general, alternatives to road salt are still being researched and tested throughout the Midwest and Northeast, but overall costs tend to be higher for these products. Less environmentally damaging products such as CMA, however, can be used selectively to protect sensitive areas like wetlands without dramatically increasing overall cost to the highway authority.

Table 4.28: Advantages and disadvantages of road salt and alternative deicing chemicals.

Type	Advantages	Disadvantages
Road salt	– Low cost ($30-40/ton) – Readily available	– Impact on the environment – Corrosivity
Alternative deicing chemicals	– Reduced corrosivity – Reduced impact on the environment – $CaCl_2$ can be used in very low temperatures (-20ºF)	– Higher cost (from a couple hundred dollars per ton to a couple thousand per ton) – CMA starts to act at a slower rate than salt

(3) *Proper deicing chemical storage.* Storage buildings for deicing chemicals minimize the likelihood of polluting surface and ground waters with contaminated runoff and eliminate the economic cost of chemicals that are dissolved and washed away by precipitation. A permanent under-roof storage facility is the best way to protect chemicals from precipitation and runoff, but where this is not possible, salt piles and chemical containers should be stored on impermeable bituminous pads and covered with a tarp or other waterproof cover.

Information Resources

The California Regional Water Quality Control Board produced *the Erosion and Sediment Control Field Manual* for the San Diego Region in 1998. To order, send a printable order form, which is available at *www.swrcb.ca.gov/stormwtr/orderform.html*, along with payment, to P.O. Box 791, Oakland, California 94604-0791.

The Federal Highway Administration published a study by Dorman et al. (1996) called *Detention and Overland Flow for Pollutant Removal From Highway Stormwater Runoff*, which provides guidelines for the design of management measures for the removal of pollutants from highway stormwater runoff. The guidelines are based on the results of field and laboratory studies to verify design procedures and assumptions and the review of other studies. For a copy of this document, contact FHWA's Office of the Natural Environment by sending an email to environment@fhwa.dot.gov.

Fisheries and Oceans Canada published *Protecting Fish and Fish Habitat: Bridge Construction and Demolition*, which is a fact sheet that details the hazards to aquatic life of bridge construction and demolition and recommends practices to reduce environmental damage. This document is available at *www.qc.dfo_mpo.gc.ca/iml/en/env/habitat/pont.htm*.

In 1992, Northern Virginia Planning District Commission and Engineers Surveyors Institute produced the *Northern Virginia BMP Handbook: A Guide to Planning and Designing Best Management Practices in Northern Virginia*. This handbook is available for download at *www.novaregion.org/pdf/NVBMP_Handbook.pdf*.

Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs (Schueler, 1987), is available for purchase from the Metropolitan Washington Council of Governments at *www.mwcog.org/ic/87703.html*.

The Staff Transportation Board of the National Research Council produced a primer for a study entitled *Environmental Impact of Construction and Repair Materials on Surface and Ground Waters*. It is written in nontechnical language and explains how the test methods and supporting computer software can provide answers to questions about the environmental impact of new construction or the repair or rehabilitation of existing highways (NCHRP, 2000). Published reports from NCHRP are available from *trb.org*.

The Transportation Research Board has published several studies that investigate the environmental impacts of activities related to transportation infrastructure. These publications are available at *www4.trb.org/trb/onlinepubs.nsf*.

The Natural Resources Conservation Service (1992) published *Soil Bioengineering for Upland Slope Protection and Erosion Reduction,* which provides specifications for installing bioengineering practices to reinforce slopes and prevent erosion. This document is available for download at *www.engr.colostate.edu/~cwatson/ce_old/CE_610_class_notes_S02/scs_1992.pdf*.

The U.S. Department of Transportation's (1995) *Best Management Practices for Erosion and Sediment Control* can be downloaded from the DOT's online publications site at *isddc.dot.gov*.

The Federal Highway Administration (1996) published the *Manual of Practice for an Effective Anti-Icing Program: A Guide For Highway Winter Maintenance Personnel*, which can guide maintenance personnel in developing a systematic and efficient practice for maintaining roads in the best conditions possible during a winter storm. It describes the factors that should be understood and addressed in an anti-icing program, with the recognition that development of a program must be based on the specific needs of the site or region. It focuses on weather information, materials, and methods that will best address site conditions such as level of service, highway agency resources, climatological conditions, and traffic. The manual can be downloaded in HTML format from *www.fhwa.dot.gov/reports/mopeap/mop0296a.htm*.

The Michigan Department of Transportation (1993) conducted a detailed study on the environmental effects and costs of using several deicing products, including salt, calcium magnesium acetate, an agricultural byproduct, a magnesium chloride product, calcium chloride, a type of concrete pavement, and sand. The study can be accessed at *www.mdot.state.mi.us/mappub/deicing*. More information on alternative deicers can be found at *www.betterroads.com/articles/prod801.htm*, *www.forester.net/xw_0106_deicing.html*, and *www.wsdot.wa.gov/fossc/maint/pns/htm/resources.htm*.

The Pacific Northwest Snowfighters Association web site (*www.wsdot.wa.gov/fossc/maint/pns*) provides resources pertaining to deicing and anti-icing products and practices, such as a list of approved products, deicing specifications, a fact sheet on magnesium chloride, and testing methods and protocols for deicing products (Washington State Department of Transportation, 2002).

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